CHAPTER 3 SUMMARY

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Evolution of Atomic Theories		
Atomic theory	**Key experimental work**	**Contribution to theory**
Rutherford	-alpha particle scattering through gold foil	-nucleus
Bohr	-hydrogen spectral lines	-quantized energy levels (principal quantum number)
Quantum Mechanics	-hydrogen spectral lines made up of closely spaced lines	-secondary quantum number
	-splitting of spectral lines caused by a magnetic field	-magnetic quantum number
	-magnetism	-spin quantum number
	-wave and particle properties of light and electrons	-wave nature of electrons -wave mechanics

- Planck: first suggestion of a quantum of energy

  Bohr: first use of quantum idea in an atomic model

  Sommerfeld: idea of subshells or sublevels leading to shapes of orbitals

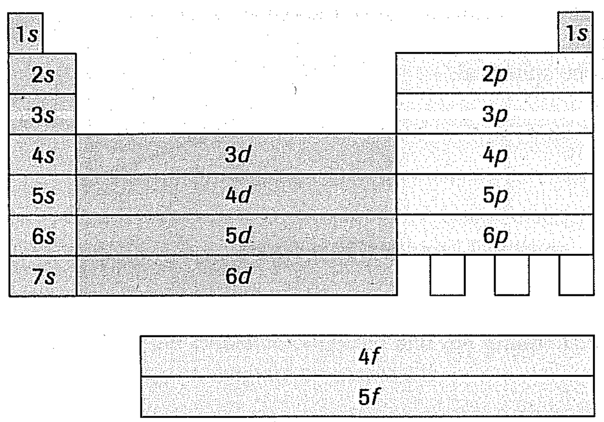
  de Broglie: idea of wave nature of electrons

  Einstein: photon theory to explain photoelectric effect using quantum idea; integral to the development of the Bohr theory

  Schrödinger: extended de Broglie's idea to develop a mathematical model of an atom based on wave mechanics

  Heisenberg: developed probability interpretation of quantum mechanics

- (a)



(b) Most of the empirical justification comes from the study of atomic spectra but other evidence also comes from physical and chemical properties of elements.
(c) Quantum mechanics theory of electron energies in orbitals.

CHAPTER 3 SELF-QUIZ

(Page 219)

1. False: The region in space where an electron is most likely to be found is called an orbital.
2. False: Electron configurations are often condensed by writing them using the previous noble-gas core as a starting point. In this system, [Ar] $3d^34s^2$ would represent vanadium.
3. False: The *f* sublevel is thought to have seven orbitals.
4. True
5. True
6. False: Rutherford knew the nucleus had to be very small because very few alpha particles were deflected when fired through a layer of gold atoms.
7. False: Electrons shifting to lower levels, according to Bohr, would account for emission spectra.
8. True
9. True
10. True
11. False: The Pauli exclusion principle states that no more than two electrons may occupy the same orbital, and that they must have opposite spins.
12. (b)
13. (d)
14. (a)
15. (c)
16. (c)
17. (b)
18. (b)
19. (d)

CHAPTER 3 REVIEW

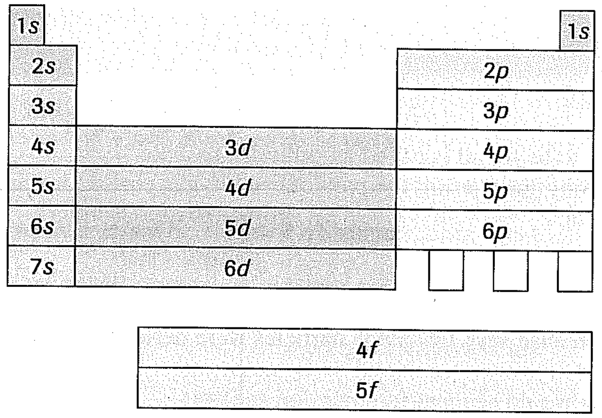
(Page 220)

Understanding Concepts

1. (a) Rutherford interpreted the deflection of alpha particles travelling through a thin foil to mean that atoms had tiny, massive nuclei.
   (b) Bohr interpreted the bright-line spectrum of hydrogen to mean that electrons exist only at specific energy levels.
2. The Rutherford model explained nothing about the nature of electrons. The Bohr model did not make acceptable predictions for atoms larger than hydrogen.
3. Orbit and orbital are terms that both refer to electrons within atoms. An orbit is a simplistic representation of a small particle in a circular path, used in the Bohr–Rutherford model. An orbital is a probability density for a wave function that "occupies" a volume of space, used in the visualizing of the quantum mechanical model.
4. The main kind of experimental work used to develop the concepts of quantum mechanics was spectroscopy, specifically the analysis of bright-line spectra.
5. (a) Quantum is a term referring to a smallest unit or part of something.
   (b) Orbital is a term describing a volume of space that is "occupied" by an electron.
   (c) Electron probability density describes the calculated likelihood of locating an electron at any point within a given volume of space.
   (d) Photon is a quantum of electromagnetic energy— a smallest "piece" or "package" of light.
6.

   $2p$ ↑↓ ↑ ↑
   $2s$ ↑↓
   $1s$ ↑↓
   oxygen atom, O

   (a) the main/principal energy level is the first number: 1,2, ...
   (b) the energy sublevel (subshell) is the letter following: *s*, *p*, ...
   (c) the orbital orientation (*x*, *y*, or *z* axis) is the respective __ line
   (d) the spin of the electron (up or down) is the arrow: ↑ or ↓
7. The idea of electron spin comes from observations of line spectra influenced by a magnetic field as well as evidence from different kinds of magnetism.

8. 

9. According to quantum mechanics, an element's properties relate to its position in the periodic table because its position is directly related to the orbital configuration of its atoms.

10.

potassium ion, K^+	sulfide ion, S^{2-}
3p ↑↓ ↑↓ ↑↓	3p ↑↓ ↑↓ ↑↓
3s ↑↓	3s ↑↓
2p ↑↓ ↑↓ ↑↓	2p ↑↓ ↑↓ ↑↓
2s ↑↓	2s ↑↓
1s ↑↓	1s ↑↓

An atom of the noble-gas argon, Ar, has the same electron orbital energy-level diagram as do these two ions.

11. (a) All of the alkali metals are soft, metallic solids with low melting and boiling points. They have high chemical reactivity, readily forming +1 ions.
   (b) We explain properties, using their electron configurations. All have a single *s* electron in the highest energy orbital, which is easily removed by the attraction of other atoms. The nearly empty valence shell creates the metallic properties—conductivity, shininess, and so on.

12. (a) $1s^2\,2s^2\,2p^6\,3s^2$
   (b) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$
   (c) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$
   (d) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^{10}\,4p^6\,5s^1$
   (e) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^{10}\,4p^6\,5s^2\,4d^{10}\,5p^6\,6s^1\,4f^{14}\,5d^{10}$

13. (a) [Kr] $5s^2\,4d^1$
   (b) [Kr] $5s^2\,4d^{10}\,5p^3$
   (c) [Xe] Ba^{2+}

14. Aluminum and titanium should be paramagnetic because these two atoms have unpaired electrons. Beryllium and mercury have atoms with filled orbitals.

15. (a) arsenic atom, As
   (b) rubidium ion, Rb^+
   (c) iodide ion, I^-
   (d) holmium atom, Ho

16. (a) $2e^-$
   (b) $8e^-$
   (c) $18e^-$
   (d) $32e^-$

17. A $2p_x$ orbital is identical to the $2p_y$ and $2p_z$ orbitals, except for orientation. It lies at 90° to the other two.

18. (a) Max Planck explained that electromagnetic energy could be released only in smallest given amounts, which he called "quanta," with the amount determined by the frequency of the radiation.
   (b) Louis de Broglie suggested that particles could have properties and characteristics of waves, and that this effect would be significant for tiny, fast-moving particles like electrons.

   (c) Albert Einstein proposed that light (electromagnetic energy) actually travels as quanta, which he called "photons," and he used this concept to explain the evidence of the phenomenon called the photoelectric effect.
   (d) Werner Heisenberg hypothesized that electron behaviour cannot ever be exactly described, but only discussed as a probability system, within limits imposed by his "uncertainty principle."
   (e) Erwin Schrödinger explained electron behaviour within the atom structure as a wave phenomenon, described by a wave mechanical equation.

19. (a) Both sodium and chlorine atoms have unfilled electron energy levels. When an electron transfers from a sodium atom to a chlorine atom, both attain the same electron configuration as a noble-gas atom. The noble gases are quite unreactive, which is thought to be due to their completely filled electron energy levels.
   (b) The occupied and empty energy levels for lithium and sodium are quite different. Therefore, electron transitions would be different, producing different colours. (It is not possible to explain or predict the specific colours in this course.)
   (c) Both sodium and silver atoms can obtain a more stable electron arrangement of filled electron orbitals if one electron is removed from an atom and it forms a 1+ ion. A sodium ion becomes [Ne] and a silver ion becomes [Kr] $4d^{10}$. Combined with a chloride ion (1–), the formulas are therefore similar.
   (d) A tin atom has the electron configuration [Kr] $5s^2\,4d^{10}\,5p^2$. This atom could lose its $5p^2$ electrons to form a 2+ ion or lose both the $5s^2$ electrons and the $5p^2$ electrons to form a 4+ ion.

Applying Inquiry Skills

20. Evidence is the basis of the scientific process. Careful evaluation of evidence is crucial, since poor evidence may lead to incorrect support of a theory, law, or generalization. Good-quality evidence can also show an existing concept to be false.

21. Useful techniques would likely include spectroscopy—possibly visible, ultraviolet, and/or infrared.

22. (a) The design is basically good but you cannot visually observe the infrared spectrum using a hand-held spectroscope. It is also questionable whether the quality of a hand-held spectroscope will be adequate. The spectrum should be photographed with a good-quality spectroscope and suitable photographic film.
   (b) This design is inadequate to identify the components of a mixture. A flame test could suggest some components, particularly certain metal ions. A qualitative analysis scheme would be necessary to identify other components.
   (c) A better design would be to crush the cereal and insert the magnet directly into the cereal. This would be more likely to attract any small bits of iron present.
   (d) The calcium in calcium sulfate is in the form of calcium ions, not calcium metal. The test with a strong magnet should be done on calcium metal.

23. (a) The analogy is good in the sense that there are certain, fixed steps like quantized energy levels. However, the analogy fails in two ways. Electron energy levels are not evenly spaced and quantum mechanics has no picture of a particle such as an electron physically moving from one location to another.
   (b) The computer simulation can be useful to illustrate some characteristics suggested by the quantum mechanics if using a probability interpretation, not a wave model. Nevertheless, the computer program that is based on some simplified view of quantum mechanics cannot be used to test the theory. Only experimental evidence can provide this kind of a test.

Making Connections

24. (a) Some examples of benefits to medical diagnosis might include light spectroscopy, which is used to identify substances present in the body; MRI scanning, which allows examination of the interior of the body; and lasers, which allow illumination and examination of the body interior through fibre-optic devices.
   (b) Some possible answers and perspectives might include:
   Economically, government funding of "pure" research is expensive; and the area does not include a profit or "payback" component.
   Socially, the benefits to society from increased knowledge inevitably advance our standard of living in our understanding of the atom.
   Scientifically, the entire scientific community constantly lobbies for funding for research to satisfy the *desire to know*.

25. (a) Rutherford won the Nobel Prize for Chemistry in 1908, for the concept of the nuclear atom, for the theory of radioactive disintegration, and for determining the nature of the alpha particle. Soddy won the Nobel Prize for Chemistry in 1921, for the discovery of (explaining the nature of) isotopes of elements.
   (b) Every aspect of modern technological society that has to do with radioactivity or nuclear energy in any form is to some extent directly dependent on work done by Rutherford and Soddy. This includes nuclear power generators, radioisotope uses in industry, research, analysis, and medicine, and our understanding of geologic processes, among many others.

Analysis

(d) According to the evidence collected, solid 1 is network covalent, 2 is ionic, 3 is metallic, and 4 is molecular.

Evaluation

(e) Most of the evidence was sufficient to classify the majority of the solids. The classification of the network covalent solid fits with the properties of network covalent solids but was done mainly by elimination once the others were classified. This classification is very uncertain and it is possible that solid 1 may be a low-solubility ionic solid. The classification of solids 2, 3, and 4 seems relatively certain.

Other properties such as hardness and melting points would help to make the classification more certain.

CHAPTER 4 SUMMARY

(Page 280)

Force or bond	Central particle	Surrounding particles
covalent	electron pair	nuclei
covalent network	electron pair	nuclei
dipole–dipole	charge site	opposite charge sites
hydrogen	proton	electron pairs
ionic	ion	oppositely charged ions
London	nuclei	nearby valence electrons
metallic	nuclei	mobile valence electrons (electron sea)

Substance	Hardness	Melting point	Electrical conductivity		
			Solid	Liquid	Solution
molecular	low	low	negligible	negligible	negligible
ionic	medium to high	high	negligible	high	high
covalent network	high	very high	negligible	negligible	n/a
metallic	medium	medium to high	high	high	n/a

CHAPTER 4 SELF-QUIZ

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1. False: The shape of molecules of the rocket fuel hydrazine, $N_2H_{4(l)}$, is predicted by VSEPR theory to be pyramidal around each nitrogen.
2. True
3. False: A central atom with two bonded atoms and two unshared electron pairs has a V-shaped arrangement of its electron pairs.
4. False: Ionic substances are ionic solids, with ionic bonding.
5. False: Hydrogen bonding is possible whenever the molecule contains hydrogen atoms bonded to N, O, or F atoms.
6. False: A molecule with a pyramidal shape and polar bonds will be polar.
7. True
8. True
9. False: The end of a soap molecule that attracts and dissolves oily dirt must be nonpolar.
10. True
11. (b)
12. (b)

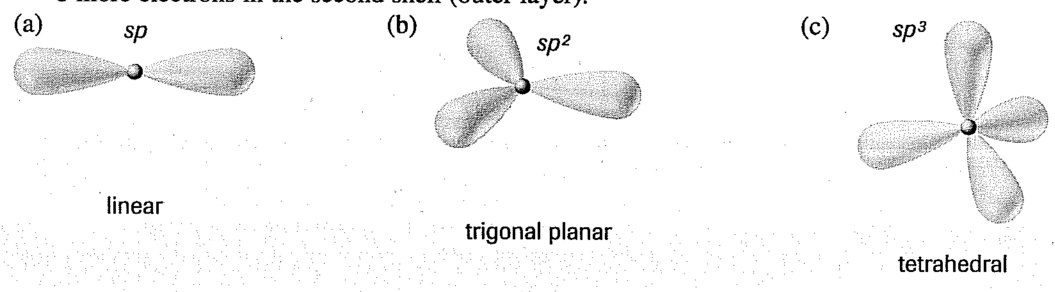
13. (d)
14. (a)
15. (c)
16. (c)
17. (c)
18. (a)
19. (b)
20. (d)

CHAPTER 4 REVIEW

(Page 282)

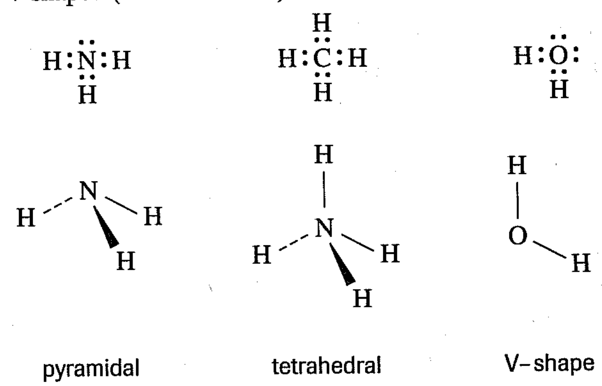
Understanding Concepts

1. (a) ·Ca· (2) (b) :C̤̈l· (1) (c) ·Ṗ̤· (3) (d) ·Ṡi· (4) (e) :S̈· (2)
2. For a covalent bond to form between two approaching atoms, both atoms must have a valence orbital occupied by a single electron (or one atom must have a vacant valence orbital and the other must have a lone pair of electrons) and the orbitals must be able to overlap in space.
3. (a) three lone pairs
   (b) one lone pair
   (c) two lone pairs
   (d) no lone pairs
   (e) one lone pair
4. (a) :F̤̈· (b) ·P̤̈· (c) K· (d) :S̤̈e· (e) ·Sr·
5. The electron configuration that gives an atom maximum stability is one with eight electrons in the shell with the highest principal quantum number (the "valence" shell).
6. (a) $1s^2\,2s^2\,2p^6$
   (b) A carbide-12 ion has 6 protons and 6 neutrons in the nucleus, with 2 electrons in the first shell (inner layer), and 8 more electrons in the second shell (outer layer).
7. (a) (b) (c)



8. (a) sp^3
   (b) sp^2
   (c) sp
   (d) sp^3
9. A sigma bond involves overlap of orbitals directly, or end to end, between the atomic nuclei.
   A pi bond involves side-by-side overlap of the two lobes of *p* orbitals above and below a line between the atomic nuclei.
10. (a) 2 sigma bonds
    (b) 3 sigma bonds and 2 pi bonds
    (c) 5 sigma bonds and 1 pi bond
    (d) 7 sigma bonds
11. The B atom has sp^2 hybridization initially, and the N atom has sp^3 hybridization (with an unshared pair of elecrons in the fourth hybrid orbital). After reaction, both central atoms must be sp^3 hybridized (they are each bonded to four other atoms). This occurs because the N supplies both electrons for the B-N sigma bond.

12. (a) Valence shell refers to the energy level of electrons with the highest principal quantum number.
    (b) Bonding pair refers to a pair of electrons shared between atoms in a valence orbital.
    (c) Lone pair refers to a pair of electrons in a valence orbital that are not shared with another atom.
    (d) Electron pair repulsion assumes that valence orbitals occupied by a pair of electrons are "full" and will repel any other full valence orbital.
13. To predict the shape of a molecule using the VSEPR model, you
    first, draw a Lewis diagram for the molecule, and
    second, count the lone pairs and bond pairs around the central atom(s), and
    finally, predict the shape around the central atom(s) from the electron pair numbers.
14. (a) linear
    (b) trigonal planar
    (c) tetrahedral
    (d) tetrahedral
    (e) linear
    (f) V-shaped
    (g) tetrahedral
    (h) V-shaped (around each O)
15. (a)



    (b) In methane, the bond angles are the normal tetrahedral angle. In ammonia, repulsion from the lone pair compresses the bond angles a bit, and in water, stronger repulsion from two lone pairs compresses the bond angle even more.
16. (a) :Ö::C::Ö:
    (b) A carbon dioxide molecule is linear, with a bond angle of 180°.
    (c) Carbon dioxide has two double bonds, each of which is strongly polar. The two bond polarities are exactly opposite and so the resultant is zero, and the molecule is nonpolar.
17. (a) An N—Cl bond is not noticeably polar, with an electronegativity difference of 0.0; whereas a C—Cl bond is polar, with an electronegativity difference of 0.5.
    (b) A molecule of $NCl_{3(l)}$ should be nonpolar because the bonds are nonpolar. A molecule of $CCl_{4(l)}$ should be nonpolar because it is symmetrical, so the bond dipoles balance, cancelling any molecular polarity.
18. (a) BeH_2 is a nonpolar molecule because it is linear and symmetrical, so its bond dipoles balance each other. H_2S is a polar molecule because it is V-shaped and not symmetrical, so its bond dipoles combine to produce a nonzero resultant dipole.
    (b) BH_3 is trigonal planar, while NH_3 is pyramidal in shape, because NH_3 has a lone pair of electrons repelling the three bond pairs.
    (c) LiH has a melting point of 688°C because solid LiH has an ionic crystal structure, with ions held together by relatively strong ionic bonding. HF has a melting point of –83°C because solid HF has a molecular crystal structure, with molecules held together by much weaker intermolecular forces.
19. The larger molecules have stronger London force intermolecular bonding because the molecules have a greater number of electrons per molecule. Therefore, the larger the molecule in this series, the higher the boiling point.
20. $CH_{4(g)}$ (–164°C), has London force; $NH_{3(g)}$ (–33°C), has London force, dipole–dipole force, and hydrogen bonding; and $BF_{3(g)}$ (–100°C), has London force. Ammonia has the strongest intermolecular bonds because of the hydrogen bonding; boron trifluoride has London force from a 32-electron molecule; and methane has weaker London force from a 10-electron molecule.

21. (a) Nickel has a much higher melting point than sodium chloride because the metallic bonding holding nickel atoms together is stronger than the ionic bonding holding sodium and chloride ions together.
(b) Solid nickel will conduct well, because the atoms' valence electrons are free to move. Solid sodium chloride will not conduct because the charges (ions) are not free to move.
(c) Solid nickel will not dissolve, because the atoms attract each other much more than water molecules can attract them. Solid sodium chloride will dissolve because the charges (ions) are strongly attracted by polar water molecules.

22. (a) Hexane has London force.
(b) 1-butanol has London force, dipole–dipole force, and hydrogen bonding.
(c) Ethylamine has London force, dipole–dipole force, and hydrogen bonding.
(d) Chloroethane has London force and dipole–dipole force.
(e) Calcium carbonate has ionic bonds.
(f) Diamond has convalent bonds.

Applying Inquiry Skills

23. (a) **Prediction**

According to intermolecular forces concepts, the order from lowest to highest solubility in water is pentane, diethyl ether, 1-butanol, and butanoic acid. Pentane, $C_5H_{12(l)}$, has symmetrical, nonpolar molecules and therefore should have little solubility in water. Diethyl ether, $(C_2H_5)_2O_{(l)}$, has polar molecules and should have some solubility in water. 1-butanol, $C_4H_9OH_{(l)}$, has polar molecules as well as the possibility for hydrogen bonding with water molecules. The solubility of 1-butanol should be high. Butanoic acid, $C_3H_7COOH_{(l)}$, is like 1-butanol but has more hydrogen bonding sites available. The solubility of butanoic acid should be very high, perhaps miscible with water.

(b) **Experimental Design**

Slowly add each of the liquids to a small quantity of distilled water until no more dissolves and two layers form. The independent variable is the substance added to the water, the dependent variable is the volume of the substance that dissolves, and the controlled variables are the volume of water and the temperature.

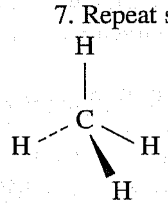
(c) **Materials**

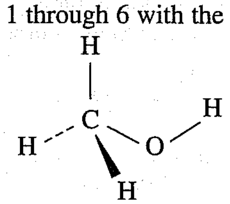
lab apron
eye protection
medium-sized test tube with stopper
5 10-mL graduated cylinders
5 droppers or disposable pipets
waste container for organic mixtures
bottle of distilled water
samples of pentane, 1-butanol, diethyl ether, butanoic acid

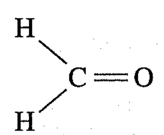
(d) **Procedure**

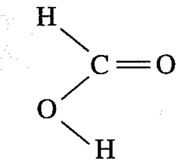
1. Measure 10.0 mL of water with a graduated cylinder and place it into the test tube.
2. Measure 10.0 mL of pentane in another graduated cylinder.
3. Start adding a little of the pentane to the water, and stopper and invert between each addition.
4. Stop adding pentane when a second layer is noticed in the test tube. Note the volume of pentane added.
5. Dispose of mixture into the labelled waste container.
6. Clean and dry the test tube.
7. Repeat steps 1 through 6 with the next liquid, until all liquids have been tested.

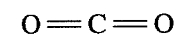
24.


tetrahedral (methane)


tetrahedral and V-shape (methanol)


trigonal planar (methanal)

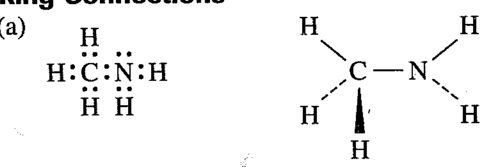

trigonal planar and V-shape (methanoic acid)


linear (carbon dioxide)

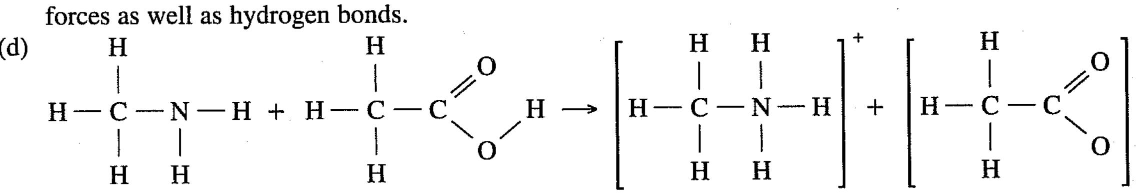
25. (a) Metallic solids are composed of atoms with mobile valence electrons—they may be thought of as an arrangement of close-packed positive ions held together by strong mutual attraction for electrons that permeate the structure. Network solids are composed of atoms held together by very strong (directional) covalent bonds.
(b) Network solids are composed of atoms held together by very strong (directional) covalent bonds. Molecular solids are composed of molecules held together by relatively weak intermolecular forces.
(c) Molecular solids are composed of molecules held together by relatively weak intermolecular forces. Ionic solids are composed of positive and negative ions held together by relatively strong (nondirectional) ionic bonds.

Making Connections

26. (a)



(b) The shape around the carbon atom is tetrahedral, and the shape around the nitrogen atom is pyramidal.
(c) Methylamine has a much higher boiling point because methylamine molecules have additional dipole–dipole forces as well as hydrogen bonds.
(d)

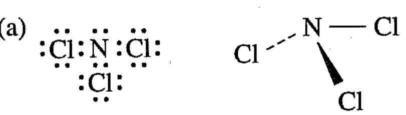


(e) Vinegar and lemon juice reduce the odour of fish because they are acidic, and react to neutralize the basic amines that cause "fishy" odours.

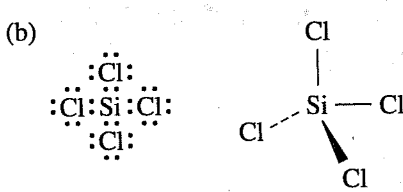
27. The material used for the skin of stealth aircraft is a carbon fibre composite material. It has fibres of carbon embedded in a matrix—the same basic type of structure as fibreglass composites, but very much stronger. The material can also be structured as a "honeycomb" to give a very high strength-to-weight ratio for solid pieces. The material is suited for radar "stealthing" because it can be made to absorb microwaves, greatly reducing any detectable reflection.

Extension

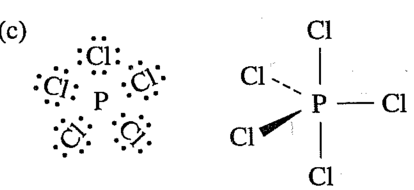
28. (a)


nonpolar

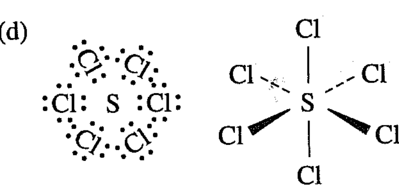
(b)


nonpolar

(c)


nonpolar

(d)


nonpolar

- Light Show Operators/Technicians
  Individuals specially trained to operate, program, service, and adjust light show lasers.

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Web Sites

http://lasereye.net/laser_eye_surgery_hawaii_kw.htm#Laser%20Types
http://www.laserist.org/Laserist/showbasics_laser.html

UNIT 2 SELF-QUIZ

(Page 286)

1. False: The term orbital refers to the volume of space an electron occupies near a nucleus.
2. True
3. True
4. True
5. False: The ground state electron configuration for all alkali metals shows that the highest energy electrons are in an *s* sublevel.
6. False: There are thought to be five *d* energy sublevels.
7. True
8. False: Schrödinger became famous by developing wave equation mathematics to describe electrons as wave functions.
9. True
10. True
11. False: VSEPR theory predicts that a central atom with three bonded atoms and one lone pair of electrons should have a pyramidal shape.
12. True
13. True
14. False: VSEPR and Lewis theories are complete enough to explain the structure and shape of the molecules in gaseous silane, $SiH_{4(g)}$, which is used as a doping agent in the manufacture of semiconductors for solid-state devices.
15. True
16. True
17. True
18. False: Ionic bonding involves three-dimensional structures with positive and negative ions attracting each other.
19. True
20. (a)
21. (b)
22. (c)
23. (a)
24. (a)
25. (a)
26. (c)
27. (d)
28. (b)
29. (d)
30. (b)

31. (b)
32. (a)
33. (b)
34. (c)
35. (a)
36. (c)
37. (b)
38. (c)
39. (a)
40. (d)

UNIT 2 REVIEW

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Understanding Concepts

1. When most alpha particles pass through the thin foil essentially unaffected, it indicates that somehow they are meeting negligible resistance; so most of the structure of the atoms they are hitting seems to be essentially empty space. When a very few alpha particles are very significantly deflected, it indicates that a tiny part of the structure of the target atoms must be relatively massive and positively charged.
2. (a) The electron was discovered as a result of the qualitative studies of cathode rays by Crookes and, in particular, by the quantitative studies of cathode rays by Thomson.
   (b) The proton was discovered as a result of the alpha particle scattering experiments by Rutherford and, in particular, by the studies of positive rays (hydrogen ions) in a cathode ray tube by Rutherford and Thomson.
   (c) The neutron was discovered as a result of radioactive decay studies by Soddy, mass spectrometer work by Aston, and, in particular, by bombarding elements with alpha particles by Chadwick.
3. (a) Atoms of an element may have different numbers of neutrons in their nuclei. These different nuclei therefore differ in mass; and, if a nucleus containing a given number of neutrons is unstable, that nucleus will be radioactive.
   (b) The term applied to such atoms is *isotope*.
4. Max Planck suggested that energy radiated from heat sources was quantized, meaning that it could not be any frequency at all, but must be a multiple of some smallest value. He could not form an equation to correctly predict the frequencies radiated without this supposition, even though it seemed completely illogical at the time.
5. Rutherford knew that a stationary electron would be attracted by, and pulled into, the positive nucleus of an atom. He thought the electrons would be orbiting just like the planets around the Sun.
6. Bohr knew that if electrons were travelling in orbits, they would be accelerating and therefore radiating electromagnetic energy constantly. This would mean that all atoms would collapse and this is not observed.
7. Bohr's First Postulate states (assumes) that electrons do not radiate energy as they orbit the nucleus because each orbit corresponds to a state of constant energy, called a stationary state.
8. Bohr's Second Postulate assumes that electrons may increase or decrease in energy only by undergoing a transition (jump) from one stationary state to another.
9. (a)

   2*p* ↑ ↑ ↑
   2*s* ↑↓
   1*s* ↑↓
   nitrogen atom, N

   (b)

   3*p* ↑↓ ↑↓ ↑↓
   3*s* ↑↓
   2*p* ↑↓ ↑↓ ↑↓
   2*s* ↑↓
   1*s* ↑↓
   sulfide ion, S^{2-}

(c)

3p ↑↓ ↑↓ ↑↓
3s ↑↓

2p ↑↓ ↑↓ ↑↓
2s ↑↓

1s ↑↓
potassium ion, K^+

(d)

2s ↑↓

1s ↑↓
beryllium atom, Be

(e)

4d ↑ ↑ _ _ _
5s ↑↓

4p ↑↓ ↑↓ ↑↓
3d ↑↓ ↑↓ ↑↓ ↑↓ ↑↓
4s ↑↓

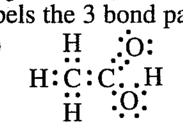
3p ↑↓ ↑↓ ↑↓
3s ↑↓

2p ↑↓ ↑↓ ↑↓
2s ↑↓

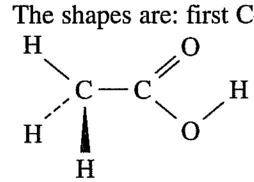
1s ↑↓
zirconium atom, Zr

10. Technetium metal has an electron configuration of [Kr] $5s^2\ 4d^5$. This means that it has five unpaired electrons in *d* orbitals. Unpaired electrons usually indicates that the substance will be at least paramagnetic and attracted by a magnet.
11. The bottom of the glass filling first is similar to the aufbau principle; lower energy levels are filled first. The level surface is similar to Hund's Rule. There should be an electron in each orbital of a level before any orbital is assigned a second electron.
12. Once you get to the fourth period in the table, the energies of the *s* and *d* orbitals of different principal quantum numbers start to cross. This means that transition metal atoms are filling the *s* orbital of a higher level while filling the *d* orbital of a lower level. In addition, some rearrangement of the distribution of electons in *s* and *d* orbitals occurs to utilize the extra stability of a half-filled or filled *d* orbital.
13. (a) Ti $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$
    (b) Tc $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^5$
    (c) Fe^{3+} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$
    (d) Br^- $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$
    (e) Se^{2-} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$
14. (a) Zr [Kr] $5s^2\ 4d^2$
    (b) Hg [Xe] $6s^2\ 4f^{14}\ 5d^{10}$
    (c) Ra [Rn] $7s^2$
    (d) I^- [Kr] $5s^2\ 4d^{10}\ 5p^6$ or [Xe]
    (e) U^{6+} [Rn]
15. An *f* sublevel consists of 7 possible orbitals which can be occupied by a maximum of 14 electrons.
16. (a) Br atom
    (b) Ag^+ silver ion
    (c) Hf^{4+} hafnium(IV) ion
    (d) In indium atom
    (e) S^{2-} sulfide ion

17. For an ionic bond to form between two approaching neutral atoms, one must have valence orbitals nearly full of electrons, and the other must have several valence orbitals that are vacant (contain no electrons) or contain very few valence electrons.
18. The primary factor in the packing of ions is the electric charge on the ions. Another factor is the size of the ions.
19. For a hydrogen bond to form between two molecules, one must have at least one nitrogen or oxygen atom in its structure, and the other must have at least one hydrogen atom bonded to a nitrogen or oxygen in its structure.
20. (a) :Ṡe· (b) ·Sn· (c) ·Ca· (d) ·In (e) ·Ba·
21. Elements with electron configurations ending in s^1 are members of the alkali metal family. They are soft shiny metals with high conductivity of heat and electric current, and they are very reactive chemically, forming 1^+ ions.
22. Elements with electron configurations ending in p^6 are members of the noble-gas family. They are all colourless gases that are extremely unreactive chemically.
23. Elements with electron configurations ending in p^5 are members of the halogen family. They are all reactive chemically, forming 1^- ions. Their physical properties at SATP vary markedly with the size of the diatomic molecule formed, so that the two smallest atoms form gaseous elements, the next is liquid, and the larger ones are solid.
24. VSEPR is an acronym for Valence Shell Electron Pair Repulsion.
25. (a) V-shaped
    (b) tetrahedral
    (c) pyramidal
    (d) V-shaped
    (e) linear
26. NF_3 should have smaller bond angles than SiF_4 because, according to VSEPR theory, in NF_3 the lone pair of electrons repels the 3 bond pairs more than a fourth bond pair would.
27. (a)



(b) The shapes are: first C—tetrahedral; second C—trigonal planar; and the O—V-shaped.
(c)



(d) The C-H bonds are polar, the C-C bond is nonpolar, the C=O double bond is polar, the C-O single bond is polar, and the O-H bond is very polar (forms a hydrogen bond). The bond polarities do not balance each other, so the overall molecule is polar.
(e) The predominant type of intermolecular bonding between acetic acid molecules is probably hydrogen bonding.
28. Isoelectronic means having the same total number of electrons. London force may be predicted (approximately) for isoelectronic substances, because it is roughly proportional to number of electrons.
29. $H_2S_{(g)}$ should have a higher boiling point than $F_{2(g)}$ because hydrogen sulfide is a polar molecule with dipole–dipole attractions as well as London force between molecules. Fluorine is a nonpolar molecule, with only London force for intermolecular attraction. Because these two molecules are isoelectronic, we assume they have approximately equal London force. VSEPR theory allows prediction of their molecular shape, and electronegativity tables allow prediction of their bond polarities to allow prediction of their molecular polarities.

Applying Inquiry Skills

30. (a) Helium and neon can be distinguished by determining their boiling points. Both atoms have only London forces between their molecules. Neon has a significantly greater number of electrons per molecule which means stronger London forces and a higher boiling point.

    (Alternatively, helium and neon can be distinguished by their emission spectra. Neon has more electrons and therefore, many more possible transitions to produce lines in the emission spectrum. The colour of a neon light is also well known (red) and this can be used to distinguish the gases.)

    (b) $MnCl_{2(s)}$ and $ZnCl_{2(s)}$ can be distinguished by testing a sample of each solid with a strong magnet. $MnCl_{2(s)}$ is paramagnetic because the Mn^{2+} ion has 5 unpaired $3d$ electrons. $ZnCl_{2(s)}$ is not paramagnetic because the Zn^{2+} ion has a $3d^{10}$ outer electron configuration with all electrons paired.

    (c) Zinc and iodine can be distinguished (other than by their appearance) by their electrical conductivity. Zinc is a metal with empty valence orbitals and with some mobile valence electrons. This makes zinc a good electrical